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Automatic mould width adjustments system of slab caster during casting

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ABSTRACT

Continuous casting of steel is a process in which liquid steel is continuously solidified into semi-finished or finished product. Depending on the dimensions of the strand, these semi-finished products are called slabs, blooms or billets. Bokaro Steel Limited has slab caster that is used to produce slabs in different dimensions. In Bokaro Steel Plant, whenever there is requirement of different sizes of slabs, it essential to stop the casting and manually adjust the mould or exchange the mould as per the required size. It requires lot of time to prepare the caster in different mould sizes. Due to manual adjustment of the mould, it affects the productivity, pains manpower for preparation of mould size as per desired grade of steel and slabs sizes, and provides delay in casting. To avoid this problem, an online mould width adjustment system is developed to provide a compact system which has the capability for fast and precise mold width adjustments during full casting speed without stopping the casting process. In this paper, the whole system is controlled using same programmable logic controller (PLC) which is used to control the slab caster.

Keywords: - Copper mould width, sensor, hydraulic actuator, PLC.

1. INTRODUCTION

Bokaro Steel Plant is one of the leading steel industries in India which is under steel authority of India limited (SAIL) and is a leading steel producer in the country. It is a fully- integrated iron and steel maker, producing both basic and special steel for domestic use like construction, engineering, power, railway, automotive, FMGC and defense industries and for sale in export markets. Continuous casting of steel is a process in which liquid steel is continuously solidified into semi-finished or finished product. Depending on the dimensions of the strand, these semi-finished products are called slabs, blooms or billets. The process was invented in the 1950s in an attempt to improve the quality of steel, energy savings, low cost and also increase the productivity of steel production [1]. Presently, most of the steel manufacturing industries worldwide are using continuous casting process [2]. Bokaro Steel Plant produces slabs using slab caster. It has the rated capacity of 18heats (1heat=280tons of liquid steel) with single casting machine and 30heats/day (equivalent to 3.0 million tons per year) with two casting machines each having two strands. Bokaro Steel Plant produce slabs of thickness 200mm-225mm and width varying from 940mm-1850mm. Size of slabs are totally depends on the mould of casting machine. Continuous Casting Shop (CCS) at Bokaro Steel Plant opened the door for meeting several challenging tasks for improving the productivity and quality of the product. One of the challenges is automatic mould width adjustment during casting at full casting speed.

Mould is one of the most critical components of casting process, which controls the initial solidification and surface quality of steel [3]. Mould is the heart of caster where the solidification process starts. A little difference may affect the productivity or quality of cast slabs. At Bokaro Steel Plant, straight mould is used and is made of copper plate, with 900mm length, 2000mm width and thickness 200-225mm as shown in Fig 1. Liquid steel is pouring on the top of the mould and at bottom side of the mould semi-solidified slab is withdrawal. The main advantages of the straight mould are:

- Better quality of the slab through flotation of non-metallic inclusions.
- Uniform contact with shell.
- Longer life and less replacement time.

In Bokaro Steel Plant, whenever there is requirement of different size of slabs, it essential to stop the casting and manually adjust the mould or exchange the mould as per required size of the final product. It requires lot of time to prepare the caster for different product sizes. Due to manual adjustment of mould, it affects the productivity, requires manpower for preparation of mould size as per desired grade of steel and slabs sizes, and provides delay in casting. To avoid the above mention problems, an online mould width adjustments system is designed. This automation will provide for flexible and rapid slab width adjustments at full casting speed i.e. automatically change the size of mould during casting as per desire grade and slab size. In this paper, an online mould width adjustment system is developed to provide a compact system which has the capability for fast and precise mold width change during full casting speed without stopping the casting process.

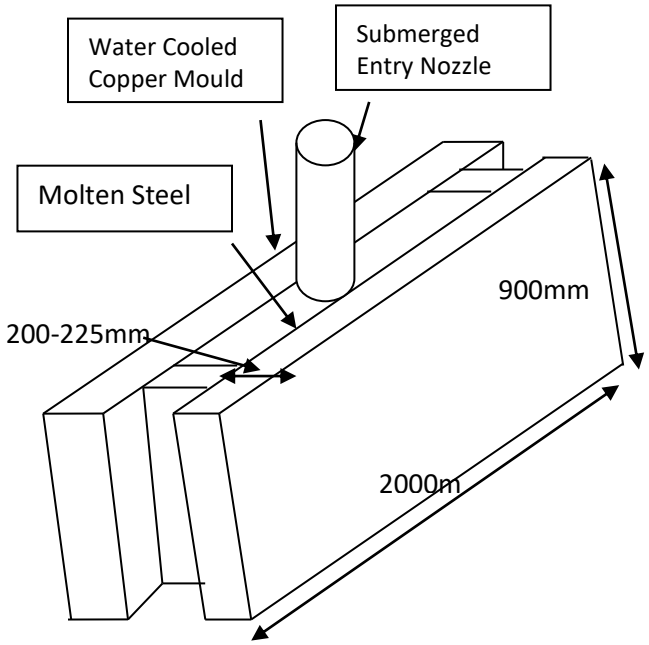

Figure 1 Cupper Mould

2. AUTOMATION IN STEEL INDUSTRIES

In today's scenario, Automation is a very important factor in almost all industries. The utility of automation is mainly of 2 types i.e. Drives (AC & DC) & PLC. The purpose of Drive Automation is for Energy Conservation, Speed Control & Torque Control, Process Control as well as Precision Quality control of Production. Automation in the field of iron and steel industries is very common now a day. Through Automation in the process industry, manifold objectives of business like improvement in the working condition for the employees at the work place, productivity in the shops as well as quality of products are achieved. It is observed that due to automation introduced, the working condition of the employees has improved drastically. The operating personal strength is reduced by 25% and the overall production cost is reduced by 20% [4]. Automation units in Bokaro Steel Plant are: Hot strip mill, Cold rolling mill, Steel Melting Shop-2, Continuous casting shop, Supervisory Load Control Center, Coke Ovens, Energy management, Slab yard management system, Weigh Bridges, Environment monitoring Information Systems etc.

Benefits of Automation

Several key benefits of automation on implementing in steel industries are given below [4-5].

- Reducing of Hardware i.e. Relays Logics
- Very First Fault Finding & Alarm Logging
- Easy Maintenance
- Addition or Subtraction of Systems are easy
- Efficiency Level is high
- Energy Conservation
- Preparation of MIS reports
- User Friendly
- First Scan Time
- Isolation of Supply

Level of Automation

There are mainly four level of Automation i.e. level 1, level 2, level 3, and level 4 [5]. But in Bokaro Steel Plant CCS it is up level 3 automation.

Sl. No	TYPE	DISCRIPTION
01	LEVEL 1	Using only one station, No networking, Control of Individual Machine
02	LEVEL 2	Networking possible using Profibus & Ethernet, Data logging, MMI, Analog I/O's. Communication is only through one control room
03	LEVEL 3	Everything like Level-2, but MIS Reports, Data logging to users, Remote Operations, Multi-Client Operation, Client Server Technology, and Implementation of ERP is Possible etc. Mainly it is a Total Integration Automation System.
04	LEVEL 4	Everything like Level-3, But Satellite communication is possible. Through satellite you can control the equipment from a remote area.

3. ONLINE MOULD WIDTH ADJUSTABLE SYSTEM

For flexibility in the production of slab with different widths, continuous casting must be equipped with online mould width adjustments system as shown in Fig 2. This will provide online mould width adjustment for flexible, fast and secure slab width changes at full casting speed. It allows the adjustment of widths automatically during casting without the necessity to reduce casting speed. A block diagram of online mould width adjustments system is shown in Fig 2. Here existing strand PLC is used to control online width adjustments system. Online mould width adjustments system control by existing strand PLC. The main advantages of strand controller are:

- Optimized solution allowing future expansion to additional or new capabilities
- Proven and reliable system
- Relatively independence of other unrelated process disturbances
- Fast dynamic system
- High degree of reliability
- Easy and quick integration into caster automation system by means of available standardized and tested interfaces.
- Pre-calibrated ready to install moulds, which reduce mould exchange time

In this system, PLC based hydraulic actuator (cylinder) is used to adjust the mould width [6-8]. Position of the cylinder is measured via ultrasonic linear position transducer (sensor). Position transducer is interfaces with input card of PLC. Now output card of PLC will send a signal to hydraulic actuator via junction box. Now hydraulic actuators adjust the width of the mould according to output signal of the PLC. This will continue until the target mould width is not achieved. From the connection details it is clear that online mould width adjustments system is a close loop control system.

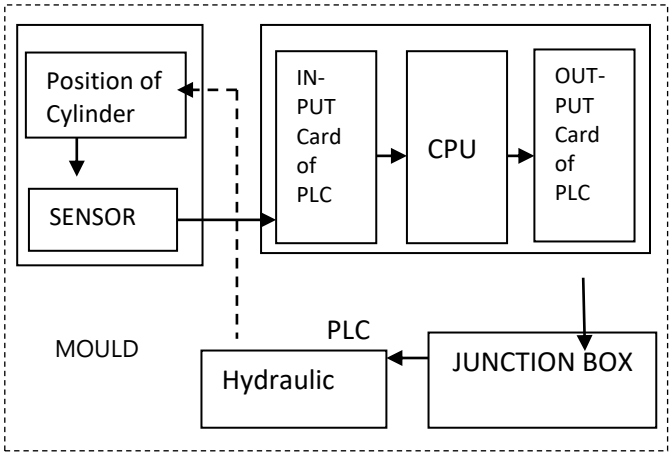

Figure 2 Connection details in block diagram of laser sensors in AMWA system

A typical schematic diagram of online mould width adjustments system is shown in Fig 3. This online system provides live mould width adjustments for flexible, faster and secure slab width changes at full casting speed. There are four cylinders attached, two at top and two at bottom position of the mould as shown in Fig 3. The position feedback of individual cylinder is measured via ultrasonic linear position transducer integrated into the cylinder. The signal output of the position transducer is interfaced to input of controller via PROFIBUS DP (decentralized Peripherals) [9-10]. The output of controller

controls the hydraulic actuator. Hydraulic actuator moves the cylinder attached to the mould and adjusts the mould width according to the position feedback of individual cylinder. This will continue until the target width is not achieved. The controller detects the disturbance within the width changes sequence and automatically initiates counter measures to bring the system in fail-safe condition.

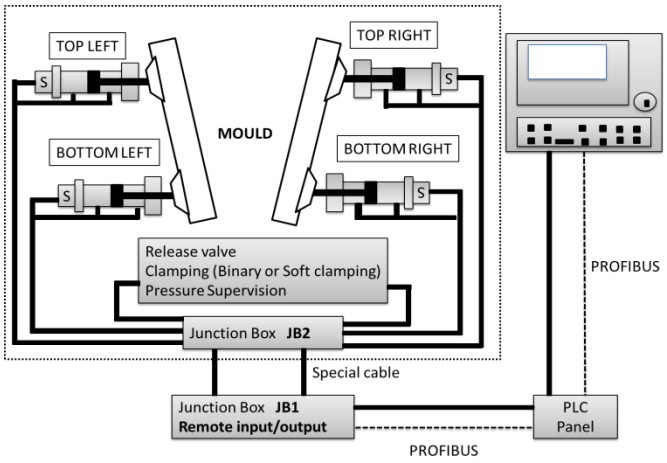

Figure 3 A typical schematic diagram of online mould width adjustments system

Width adjustment mode

Cold and warm adjustment methods are described below. This method is used both for warm adjustment (to change the mould width without stopping the casting or during casting process) and cold adjustment (to adjust the width and taper of the mould automatically before start of casting). During warm adjustment, it allows large width changes with short tapered pieces at full casting speed. To achieve this algorithm, both circular and parallel movements are performed by the narrow side copper plates. This results in a smooth and continuous support of the narrow side of the strand shell during width change. Throughout the adjustment procedure, both taper and width are continuously changed, till final width position of a taper is attained. The position and length of the tapered slab piece may be optimized according to the capability of the rolling mill.

The main advantages of this mode of adjustment are:

- Higher adjustment speed, which is suitable for higher casting speed.
- Less deformation force on the strands shell.
- Reduce copper plate wear/maintenance

Operation modes

The Mode is selected from AMWA operator panel installed on the casting platform. Following operating modes are possible:

Operation Mode	Description
OFF	All adjustment functions are locked in this mode. No movement is possible. The enable valve is de-energized to prevent any movement.
CALIBRATION	Calibration is carried out to find the offset value of position transducers, which is used for calculation of actual width. The new calibration offset values are effective only when calibration is successful and acknowledged by the operator.
MANUAL	In manual mode, the movement of individual or both sides is affected via selection on operator panel. All controls are with operator. Safety interlocks are active in this mode. In this mode, it is possible to open/close gap with fast/slow speed and also to adjust the taper. This mode is applicable only cold width adjustment.
AUTOMATIC	This mode is applicable for both cold and warm width adjustment procedure. All interlocks are active in this mode. The controls are carried out in closed loop. During cold adjustment, this mode is used to adjust the width and taper of the mould automatically before start of casting. During warm adjustment, this mode is used to change the mould width without stopping the casting process.

a) Set-point Handling

Depending on overall system configuration and current active operating mode, the set-point required for operation of AWAM is downloaded from any of the following:

- From level 2 system
- From human machine interface (HMI)
- From AWAM operator panel

When controller receives a new set-up data, it is checked for limits and validity and then accepted by the controller.

Following set-up data is required for automatic operation of AWAM:

- Target width
- Target taper
- Starting point

b) Calibration

In order to calculate the offset of position transducers and derive gape (width) between mould narrow sides from position values of transducer, calibration is carried out. It is required when the mould delivered from the maintenance shop or

component of the narrow side plates or cylinder adjustments are changed or modified. The mould is calibrated in the maintenance area during mould preparation. This greatly reduces the mould exchange time. A mobile controller is provided in the maintenance area for calibrating. Calibration can also be carried out in casting position via mould PLC. In order to calibrate the mould, it is necessary to:

- Measure the actual distance on top from the Cu-plate position to the center of mould on the right and left side.
- Measure the taper on right and left side (taper measuring device)

These values are manually entered into the entry on AMWA HMI (human machine interface).

Out of the measured tapers and positions of the narrow face copper plate, the system calculates an offset value. This offset value is the value of the difference between the measured position of the narrow side and reported position of the position transducer. The offset value are saved and stored in the position transducer. Therefore, the calibration data remains with the mould. The advantage of this solution is that a further manual width measurement check at the caster is not necessary. After connection of the mould in the caster to the width adjustment control system, the stored position values are transferred to the controller by simply pushing the "calibration" button at AMWA operator panel located close to the mould.

4. CONCLUSION

To increase the productivity and decrease the caster down time, it is essential to have automatic mould width adjustments system. In this paper, automatic system is designed; automation is released using hydraulic actuator and closed loop control system. Whole system is controlled using the same PLC which is used to control the slab caster. It has been a proposed system. The actual implementation is not carried out which may be the scope of future work.

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